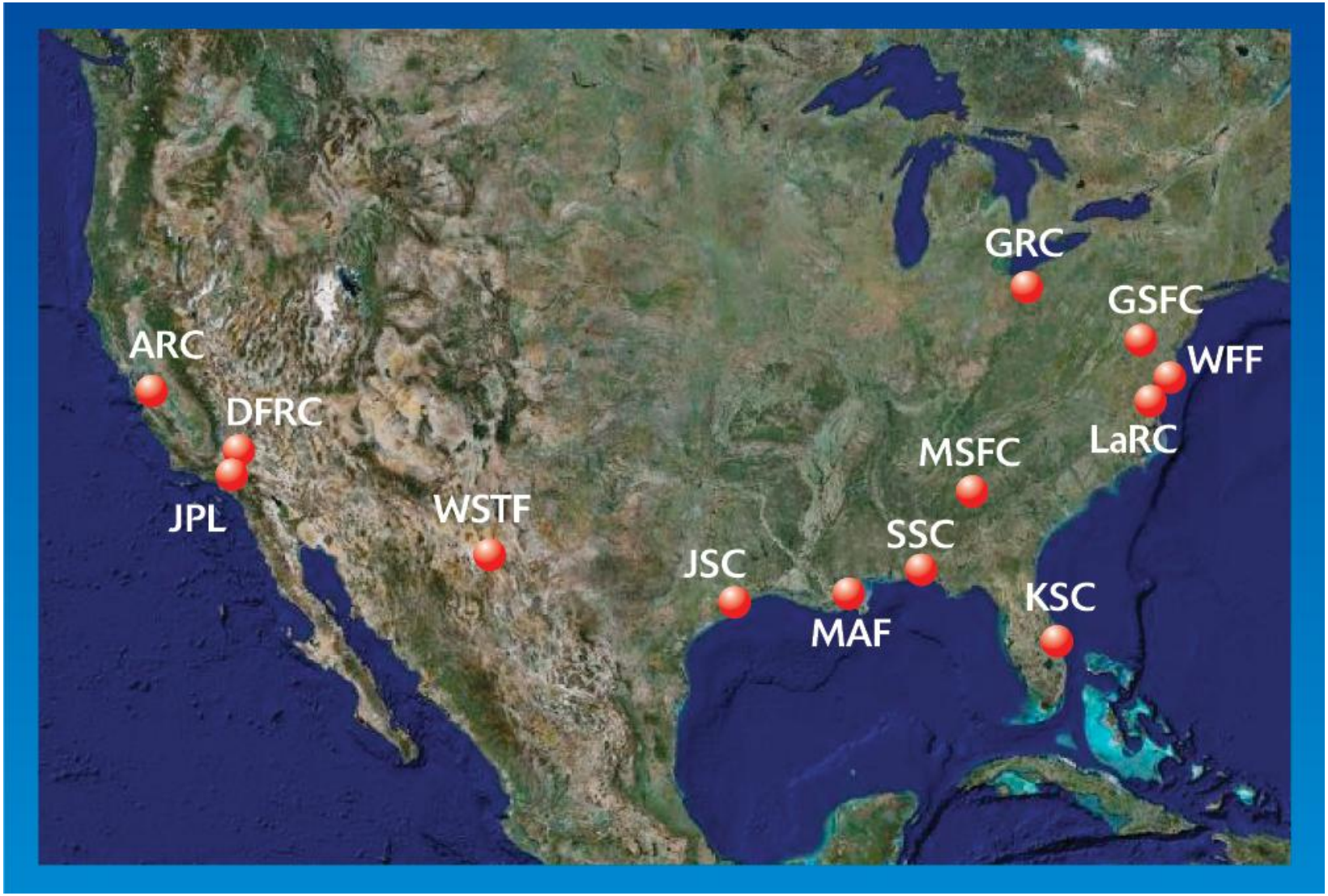
# NASA's Remediation Challenges

**David Amidei**

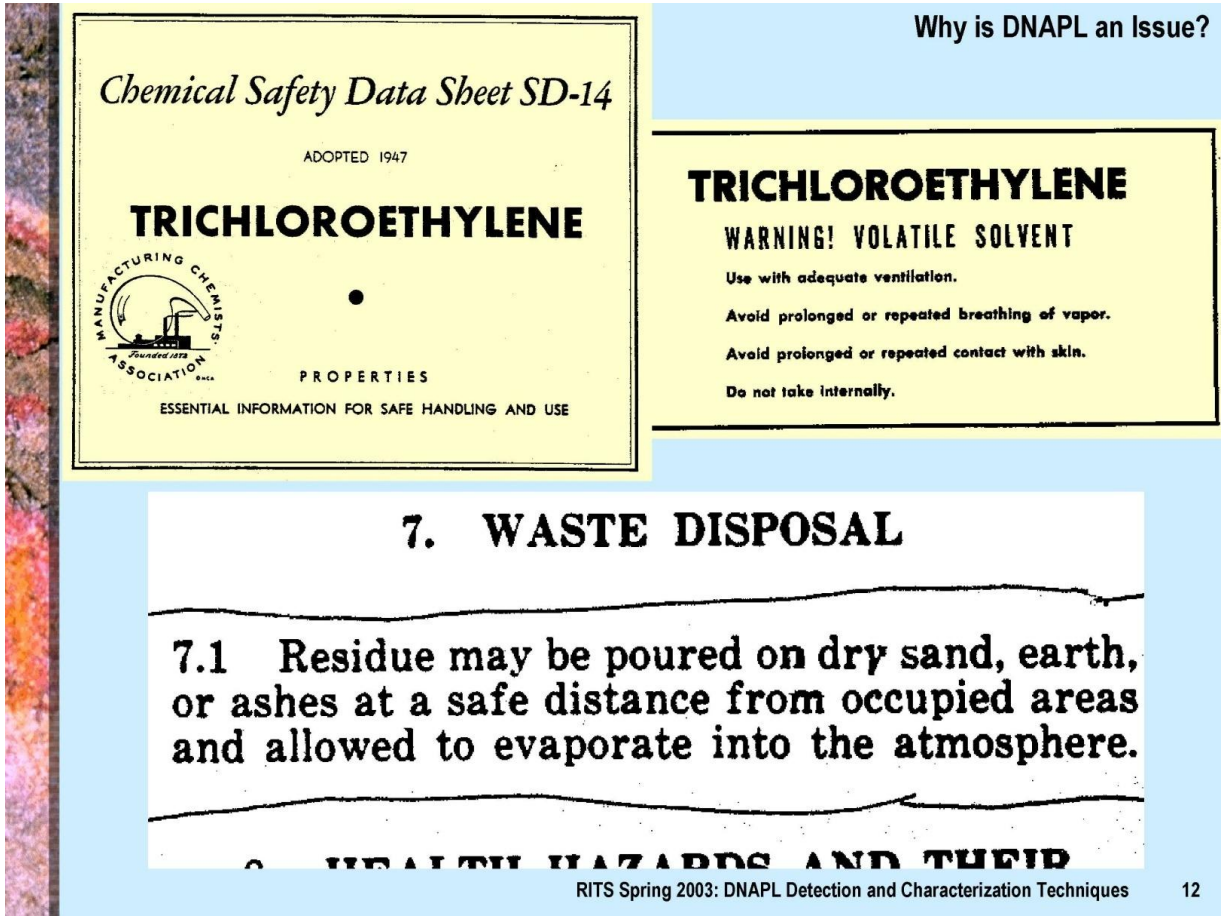
**NASA HQ**

**Environmental Management Division**

# NASA Facilities



# Previous Practices



Why is DNAPL an Issue?

*Chemical Safety Data Sheet SD-14*

ADOPTED 1947

**TRICHLOROETHYLENE**

MANUFACTURING CHEMISTS' ASSOCIATION Founded 1872

PROPERTIES

ESSENTIAL INFORMATION FOR SAFE HANDLING AND USE

**TRICHLOROETHYLENE**

WARNING! VOLATILE SOLVENT

Use with adequate ventilation.

Avoid prolonged or repeated breathing of vapor.

Avoid prolonged or repeated contact with skin.

Do not take internally.

**7. WASTE DISPOSAL**

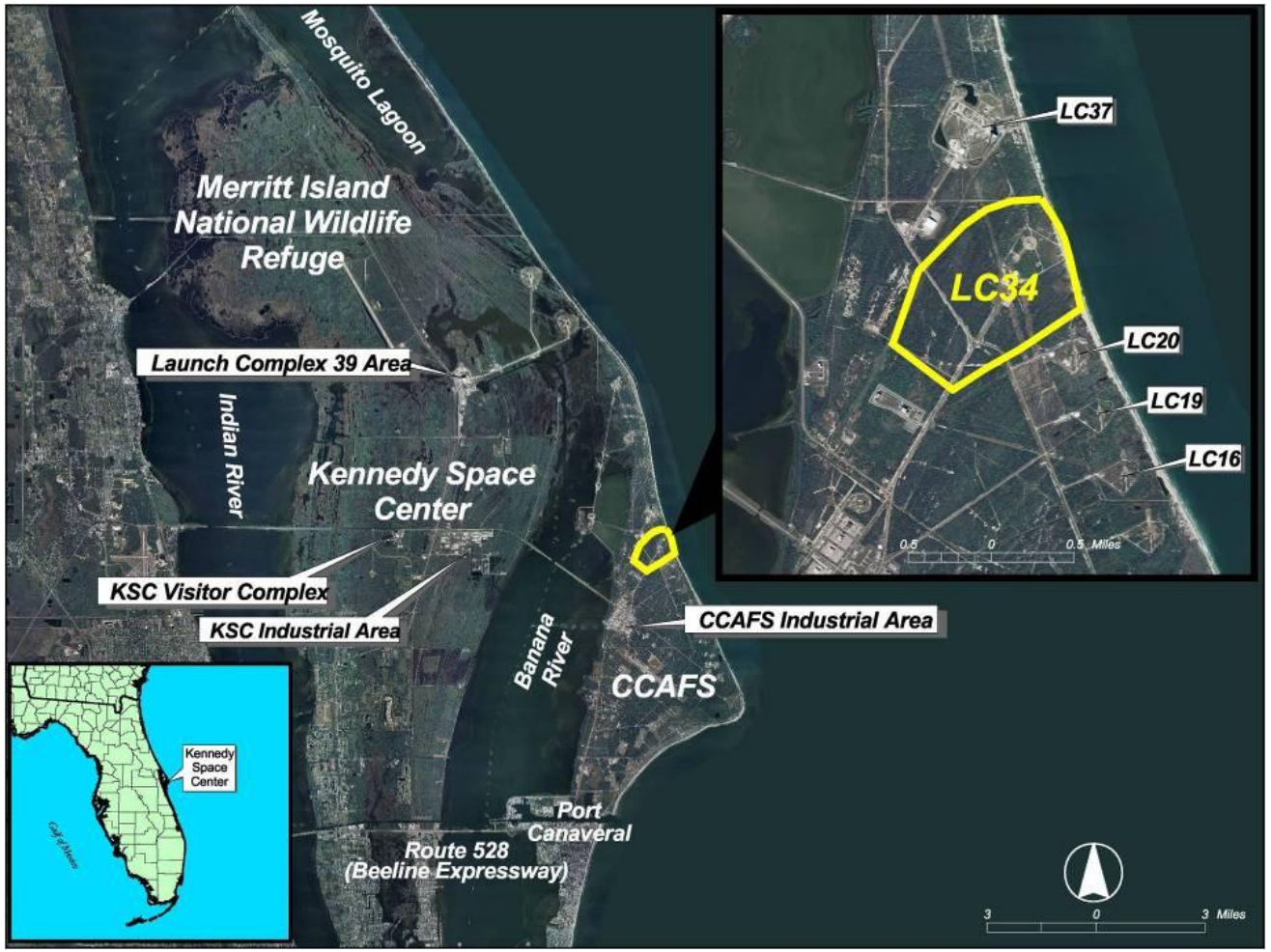
7.1 Residue may be poured on dry sand, earth, or ashes at a safe distance from occupied areas and allowed to evaporate into the atmosphere.

# …and more circa 1968

# Current Status

- **Current cleanup estimate is about $1B**
- **Drivers in that estimate include**
  - Launch Complex 34 at the Kennedy Space Center (KSC) in Florida
  - The Santa Susana Field Laboratory (SSFL) in California
  - The White Sands Test Facility (WSTF) in New Mexico

# LC-34 at KSC


Mosquito Lagoon
Merritt Island National Wildlife Refuge
Launch Complex 39 Area
Indian River
Kennedy Space Center
KSC Visitor Complex
KSC Industrial Area
Banana River
CCAFS Industrial Area
CCAFS
Port Canaveral
Route 528 (Beeline Expressway)
Kennedy Space Center
3 0 3 Miles
LC37
LC34
LC20
LC19
LC16
0.5 0 0.5 Miles

# Site History

## View From the Northeast

**1961**

**2003**

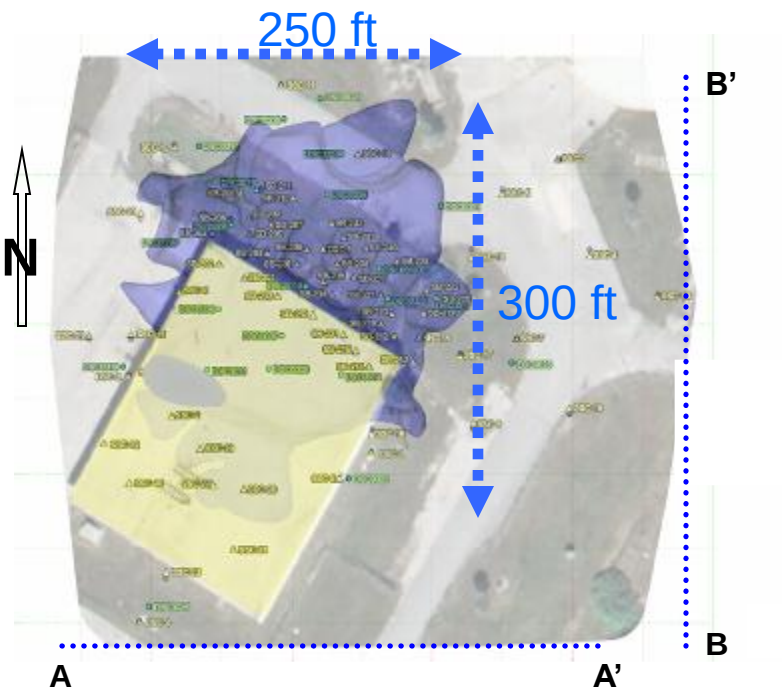
# Site History

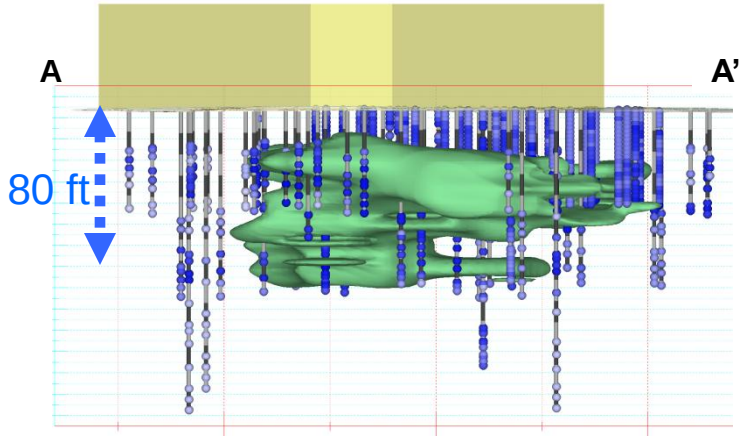
- **Constructed between 1959 and 1961 for the Saturn 1 and 1B rocket program**
  - Seven Saturn 1 and 1B launches from 1961-1968
  - Location of the Apollo 1 mishap
- **Extensive cleaning of spaceflight components with trichloroethene (TCE)**


# Contamination Description

- **~330 acre groundwater plume (1 mile by ½ mile)**
- **Groundwater contamination is present to 118 ft below land surface (bls)**
- **Sand aquifer with inter-bedded silt, clay, and shell layers (8 Layers)**
- **DNAPL (TCE) present between 18 ft & 80 ft bls**
  - Shallow Zone <45 ft bls = 41,000 lbs (saturated soil > 300 mg/kg)
  - Deep Zone >45 ft bls = 33,000 lbs (sat. soil > 300 mg/kg)
  - Additional 12,000 lbs of TCE mass in “shell” of soil surrounding DNAPL (TCE sat. soil concentrations 100 - 300 mg/kg)

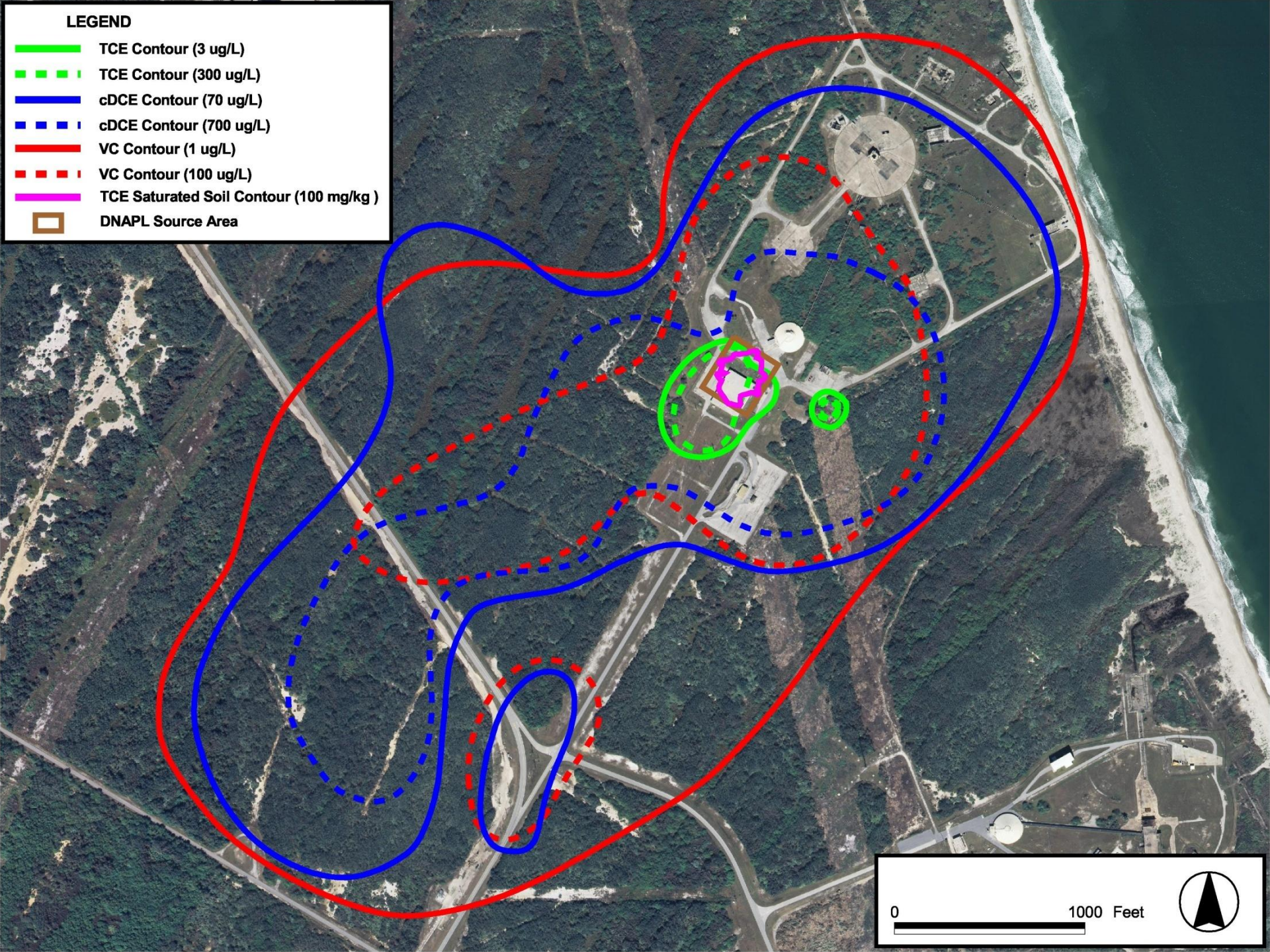
# DNAPL Source Zone





EVS solids model source zone (>300 mg/kg) based upon over 1,200 saturated zone soil samples


LEGEND
TCE Contour (3 ug/L)
TCE Contour (300 ug/L)
cDCE Contour (70 ug/L)
cDCE Contour (700 ug/L)
VC Contour (1 ug/L)
VC Contour (100 ug/L)
TCE Saturated Soil Contour (100 mg/kg )
DNAPL Source Area
0
1000 Feet

# Key Points Regarding Site Impacts

- **Dissolved groundwater plume of ~330 acres**
- **Radial groundwater flow**
- **2 acre source area with significant mass, ~100,000 lbs**
- **Large variations in hydraulic conductivity ($1x10^{-3}$ cm/sec to $1x10^{-8}$ cm/sec**
- **DNAPL extending to 80 ft bls (12,900 mg/kg @ 78 ft bls)**
- **40+ yr old release**

# Modeling Considerations

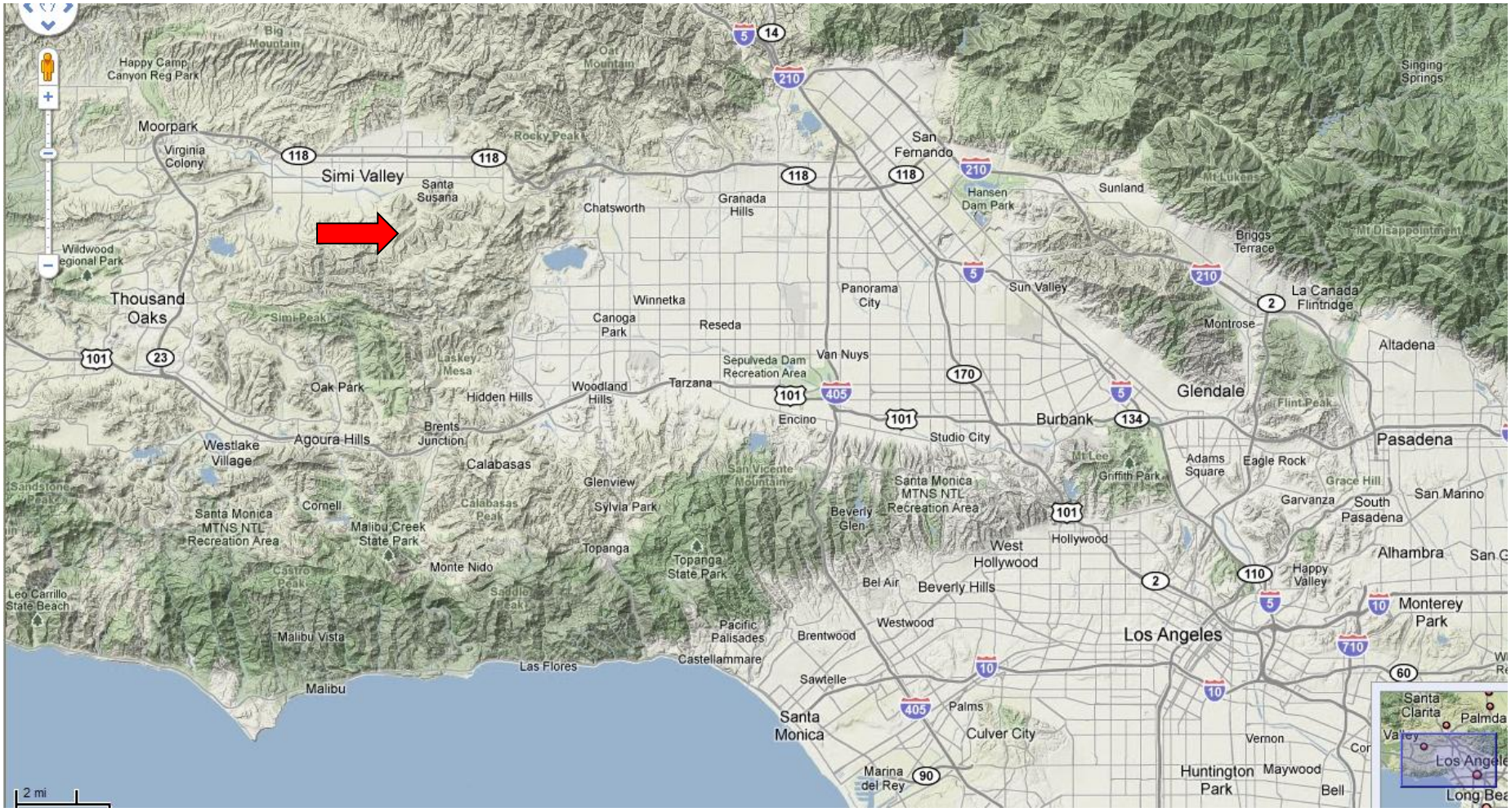
- **Groundwater modeling results**
  - No Action – >900 yrs to reach MCLs
  - 85% DNAPL Source Removal and Dissolved Plume Hydraulic Control – 750 yrs to reach MCLs
  - 99% DNAPL Source Removal (feasible?) and Dissolved Plume Hydraulic Control – 250 yrs to reach MCLs

# LC34 DNAPL Source Zone Costs

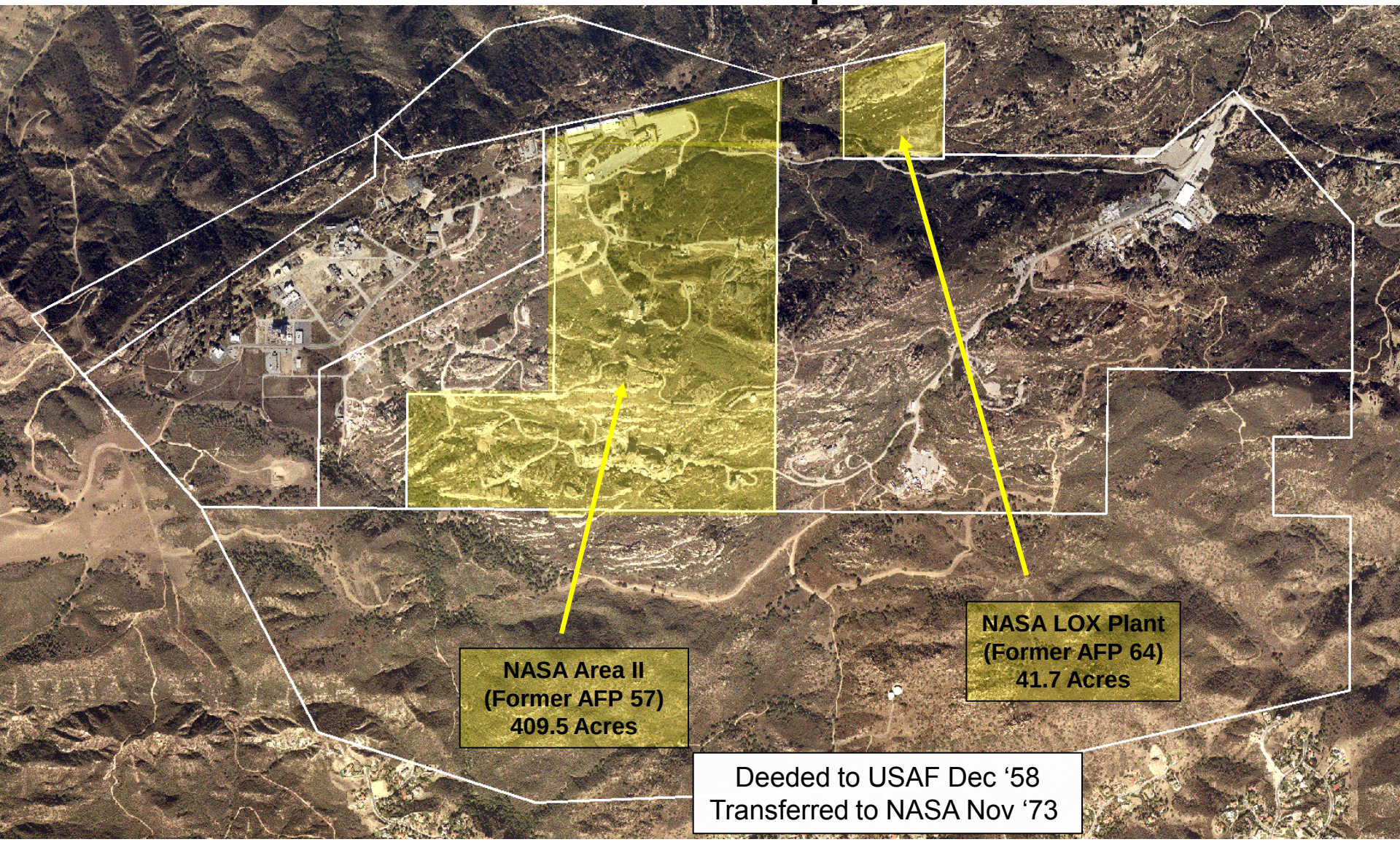
| Treatment Zones and Alternatives | First Year Cost (Capital Cost + First Year O&M&M Cost) | Total "Pay As You Go" Cost (First Year Cost + Total Non-Discounted O&M&M) | Total NPV (First Year Cost + Total O&M&M NPV) |
|---|---|---|---|
| **DNAPL Source Zone** | | | |
| Hydraulic Containment via Pump and Treat | $1M | $100M | $4M |
| Permeable Reactive Barrier | $12M | $60M | $15M |
| Enhanced Bioremediation | $5M | $45M | $10M |
| Conventional Excavation to 55 feet bls, Enhanced Bioremediation 55-85 feet bls. | $40 - $50M | $54M | $42 - $50M |
| LDA/Steam/Iron to 55 feet bls, Enhanced Bioremediation 55-85 feet bls | $50 - $70M | $100M | $55 – 75$M |
| ZVI Clay or Slurry Wall Barrier to 85 ft bls (Containment - No Treatment Provided) | $5 - $6M | $5 - $7M (based upon 30 yrs) | $5 - $6M (based upon 30 yrs) |

# Santa Susana Field Laboratory

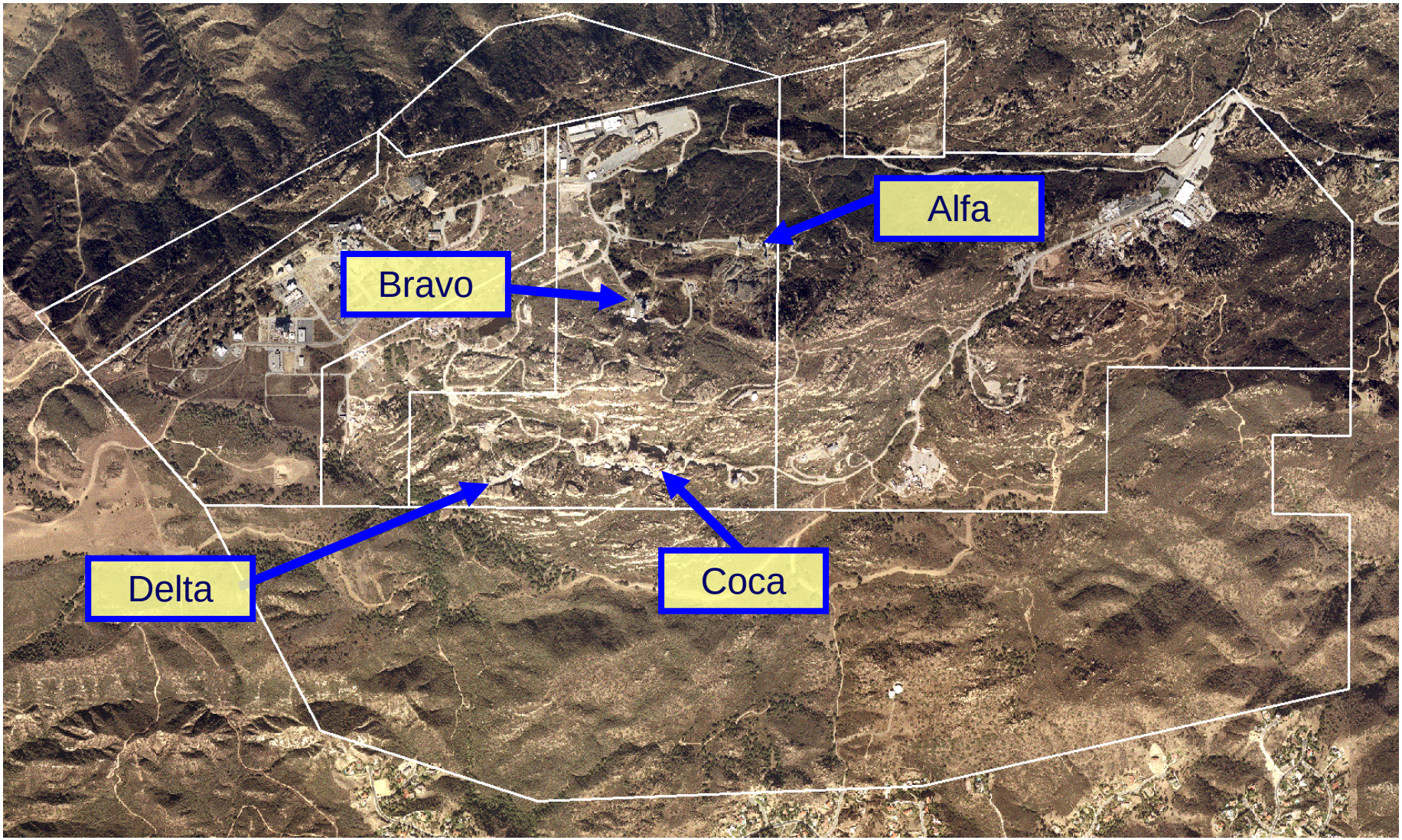
# Location Map

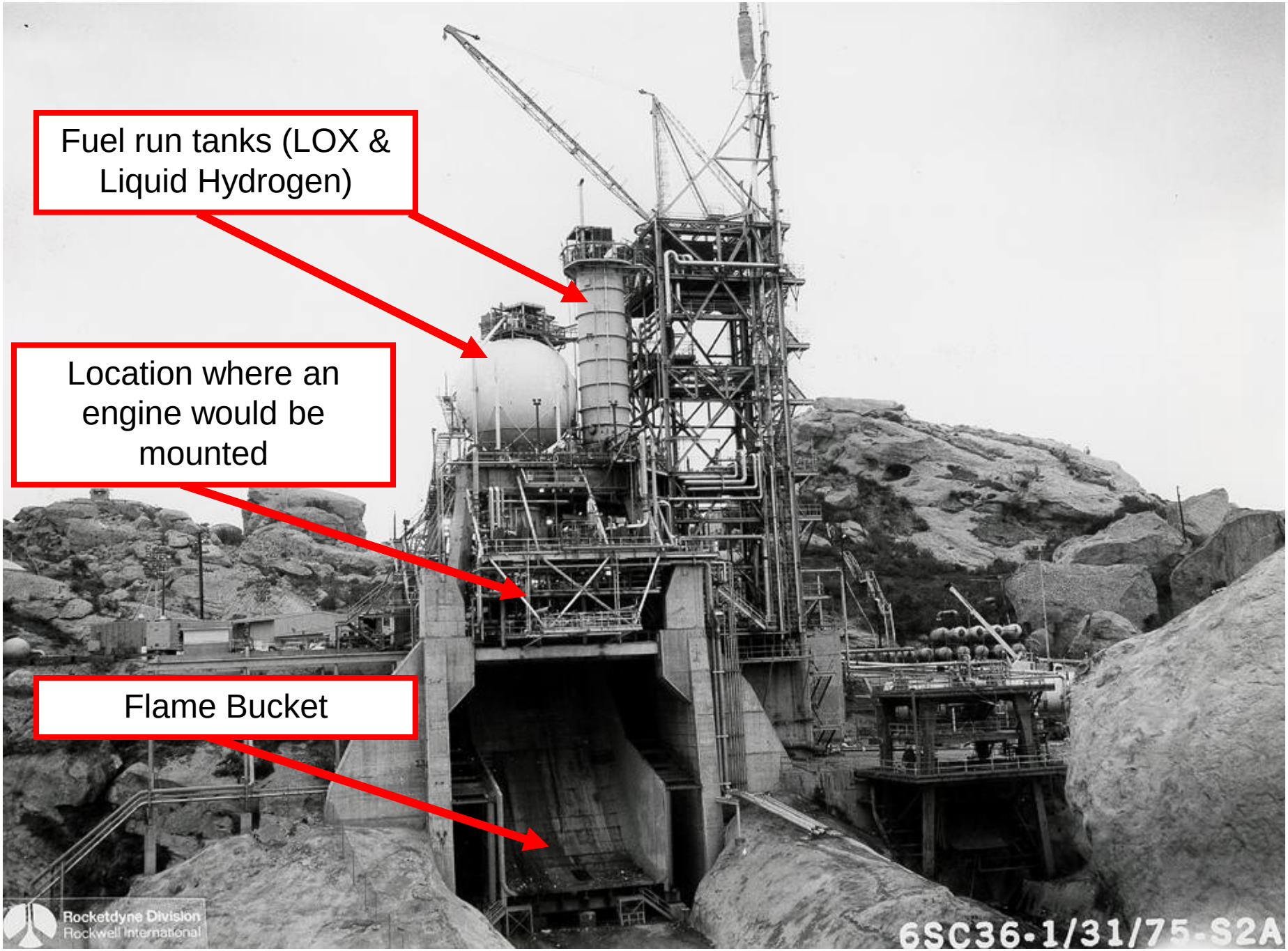


# Site Map

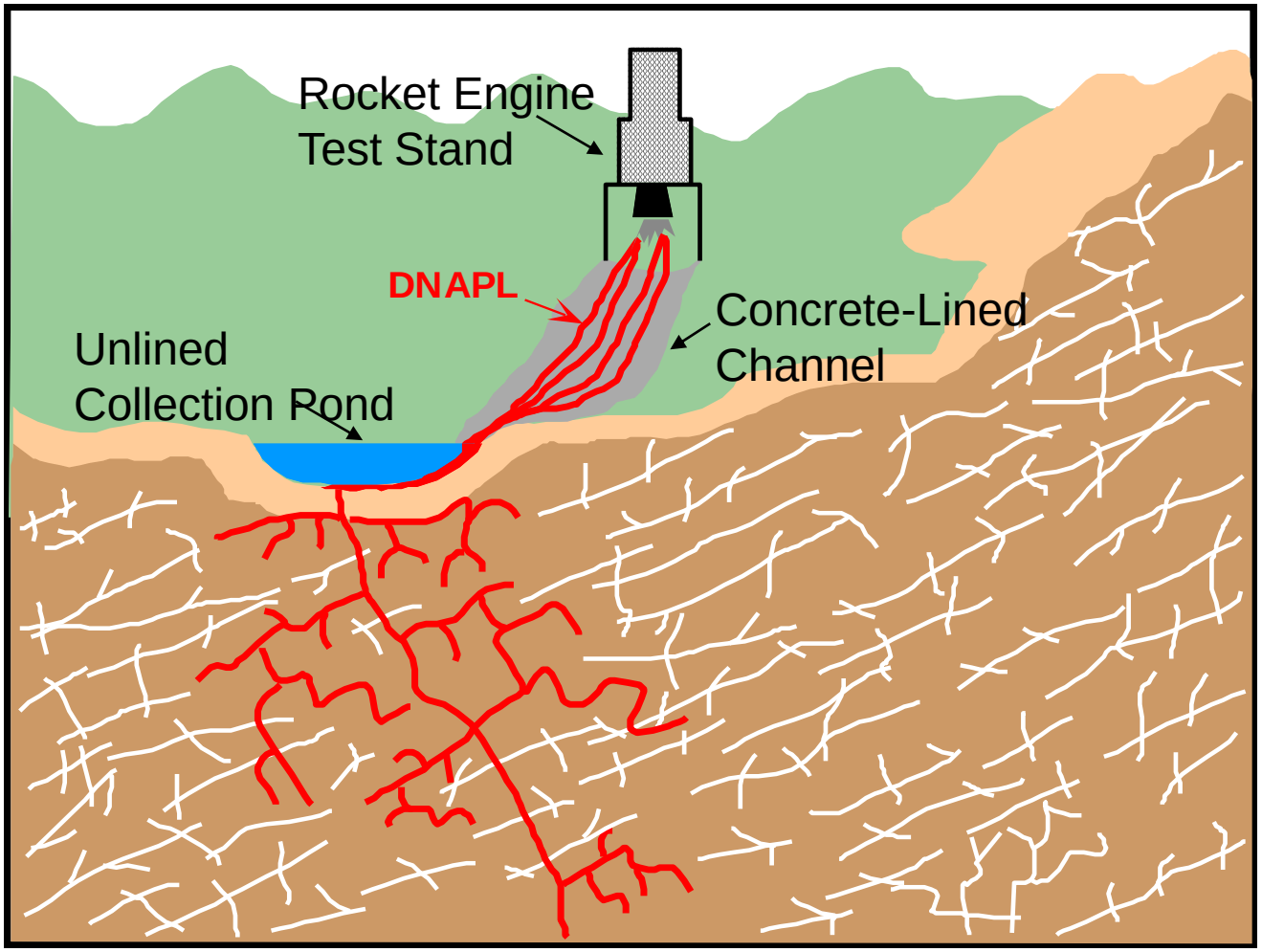

NASA Area II
(Former AFP 57)
409.5 Acres
NASA LOX Plant
(Former AFP 64)
41.7 Acres
Deeded to USAF Dec ‘58
Transferred to NASA Nov ‘73

# Test Stand Location Map



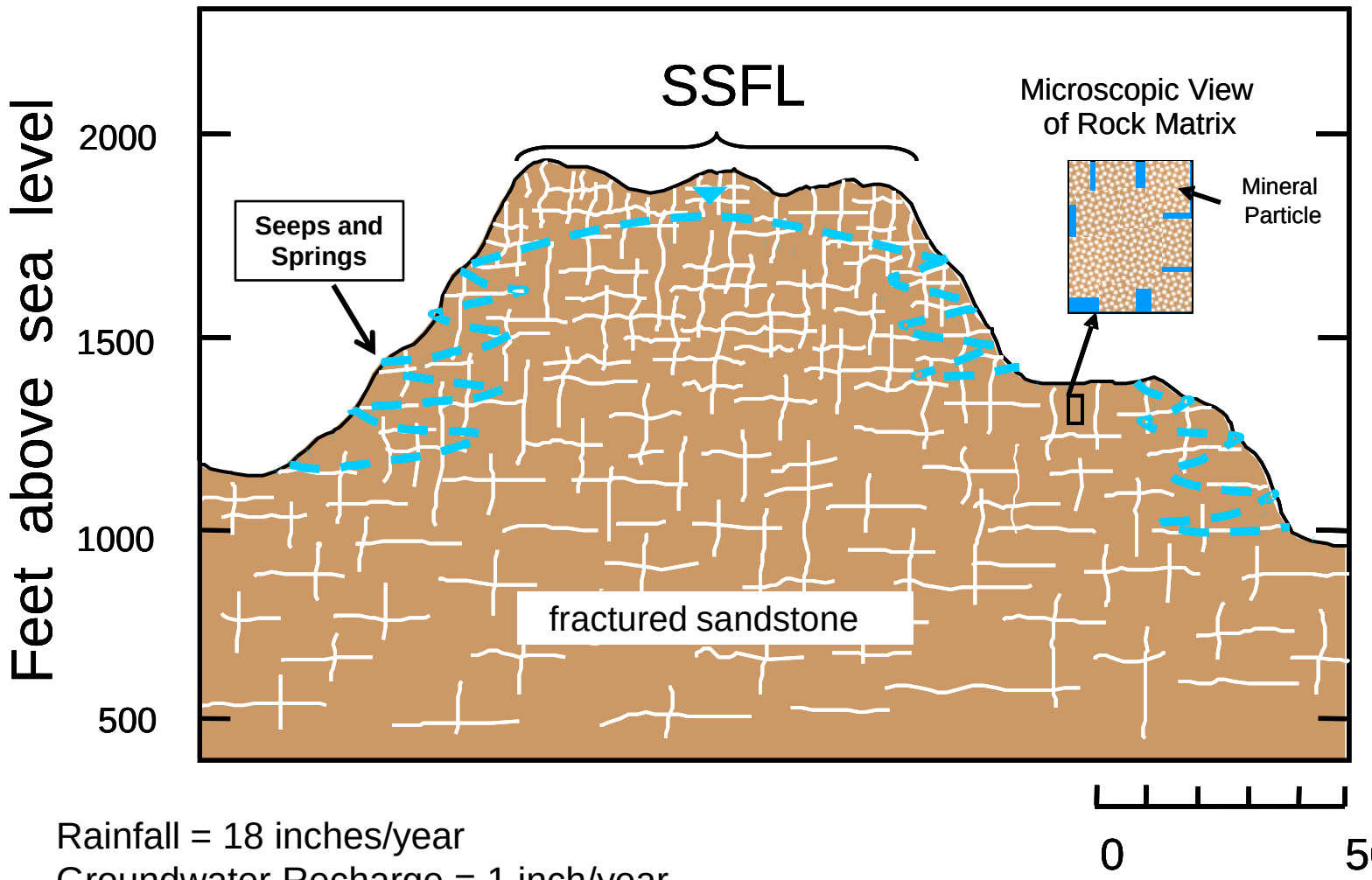

Fuel run tanks (LOX & Liquid Hydrogen)
Location where an engine would be mounted
Flame Bucket
Rocketdyne Division
Rockwell International
6SC36-1/31/75-S2A

# Why is groundwater contaminated with TCE?

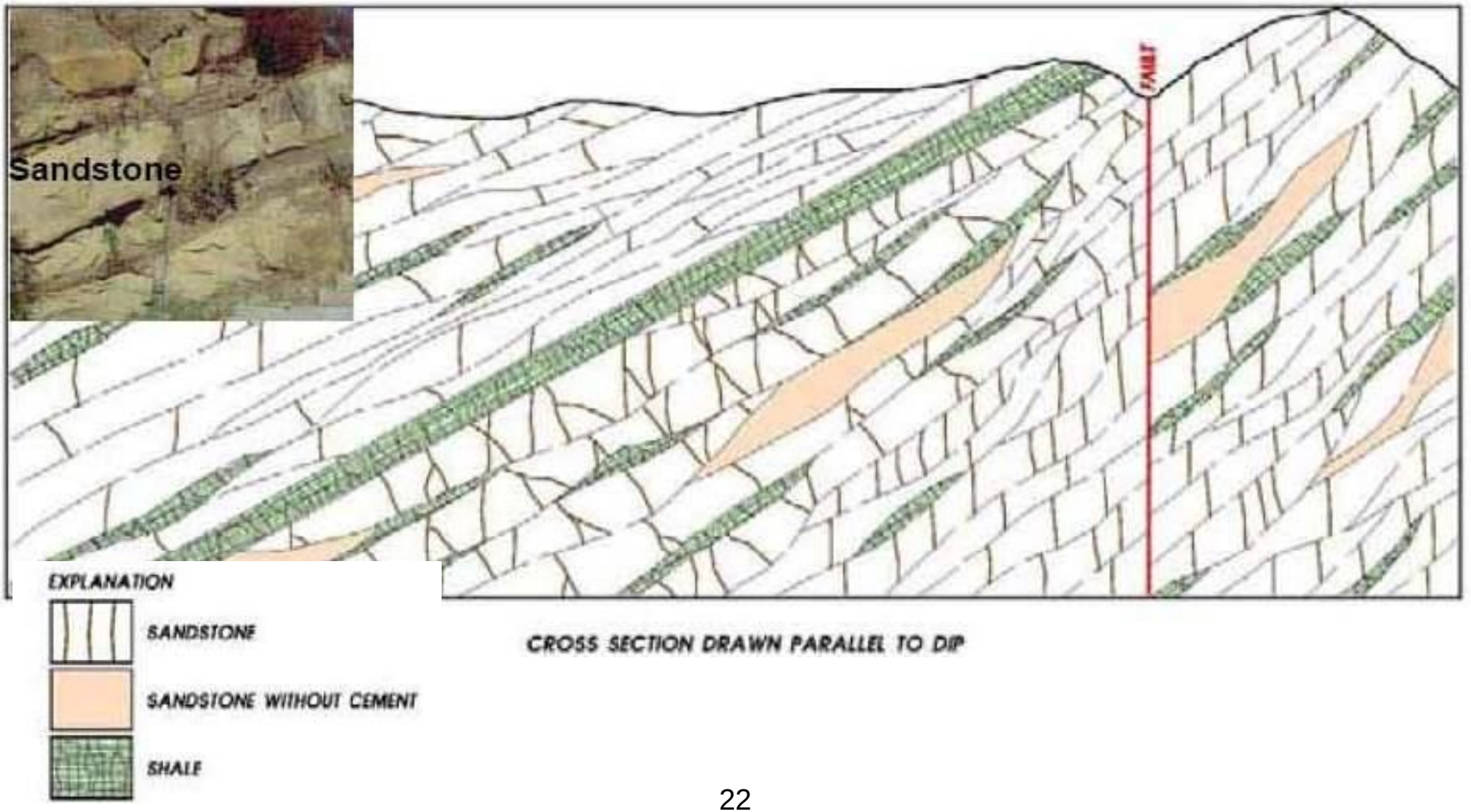



**Estimated that about 500,000 gallons (2,500,000 kg) of TCE was released to the groundwater.**

# Conceptual Groundwater Model

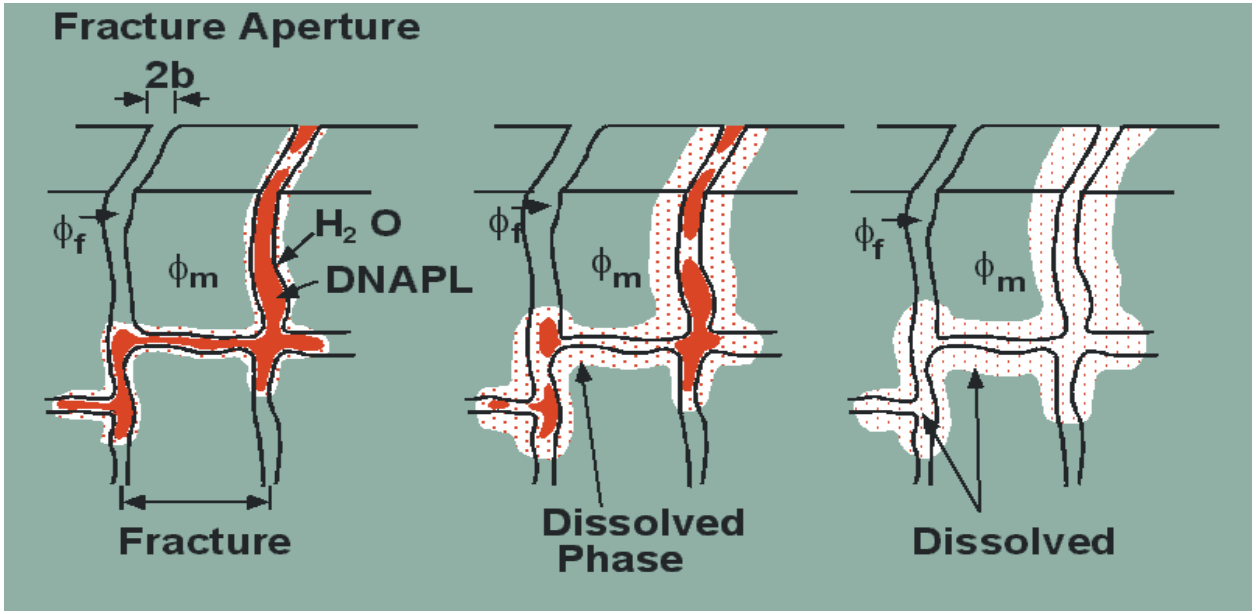



Rainfall = 18 inches/year
Groundwater Recharge = 1 inch/year

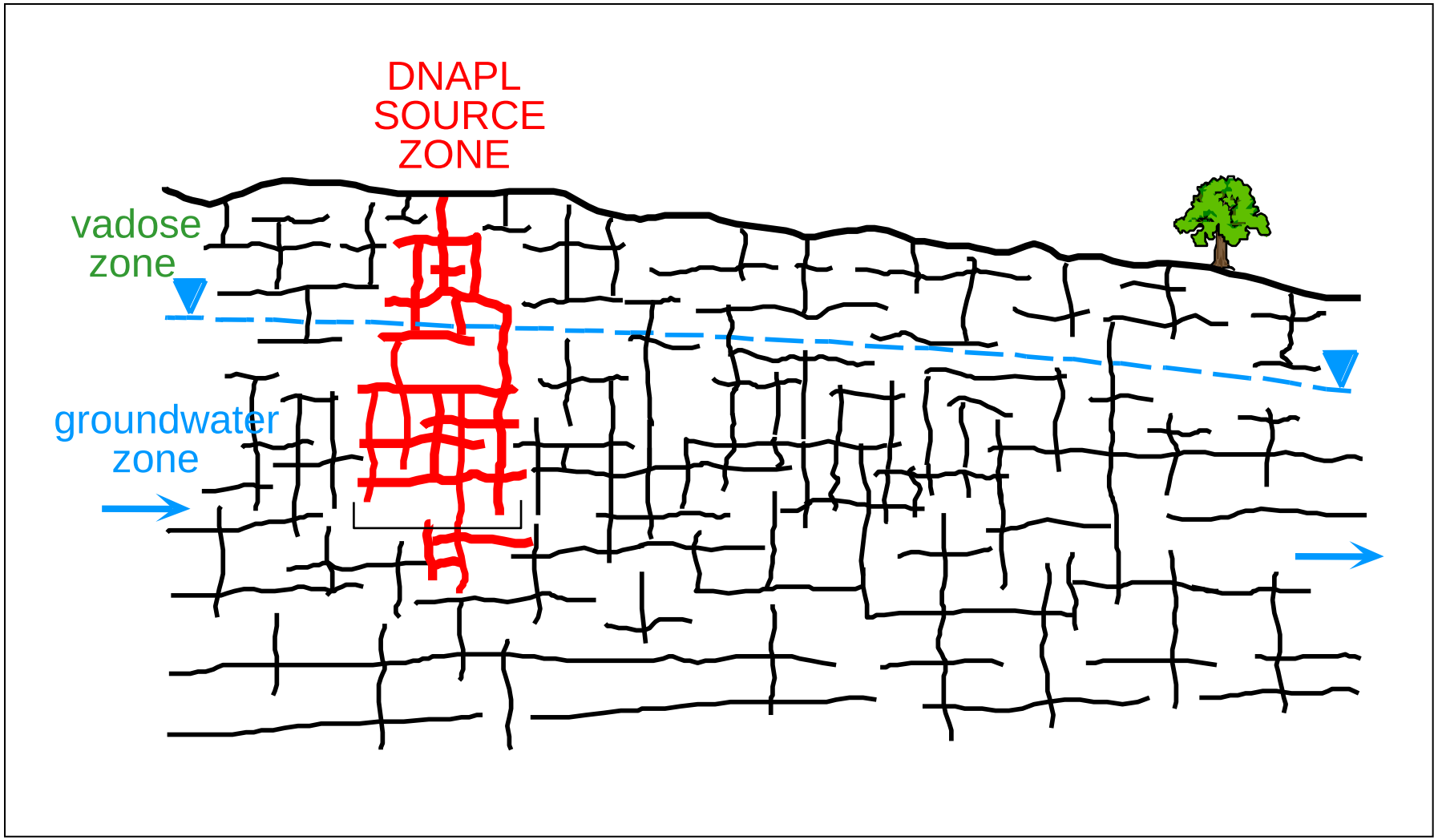

Sandstone
FAULT
EXPLANATION
SANDSTONE
SANDSTONE WITHOUT CEMENT
SHALE
CROSS SECTION DRAWN PARALLEL TO DIP

# Matrix Diffusion

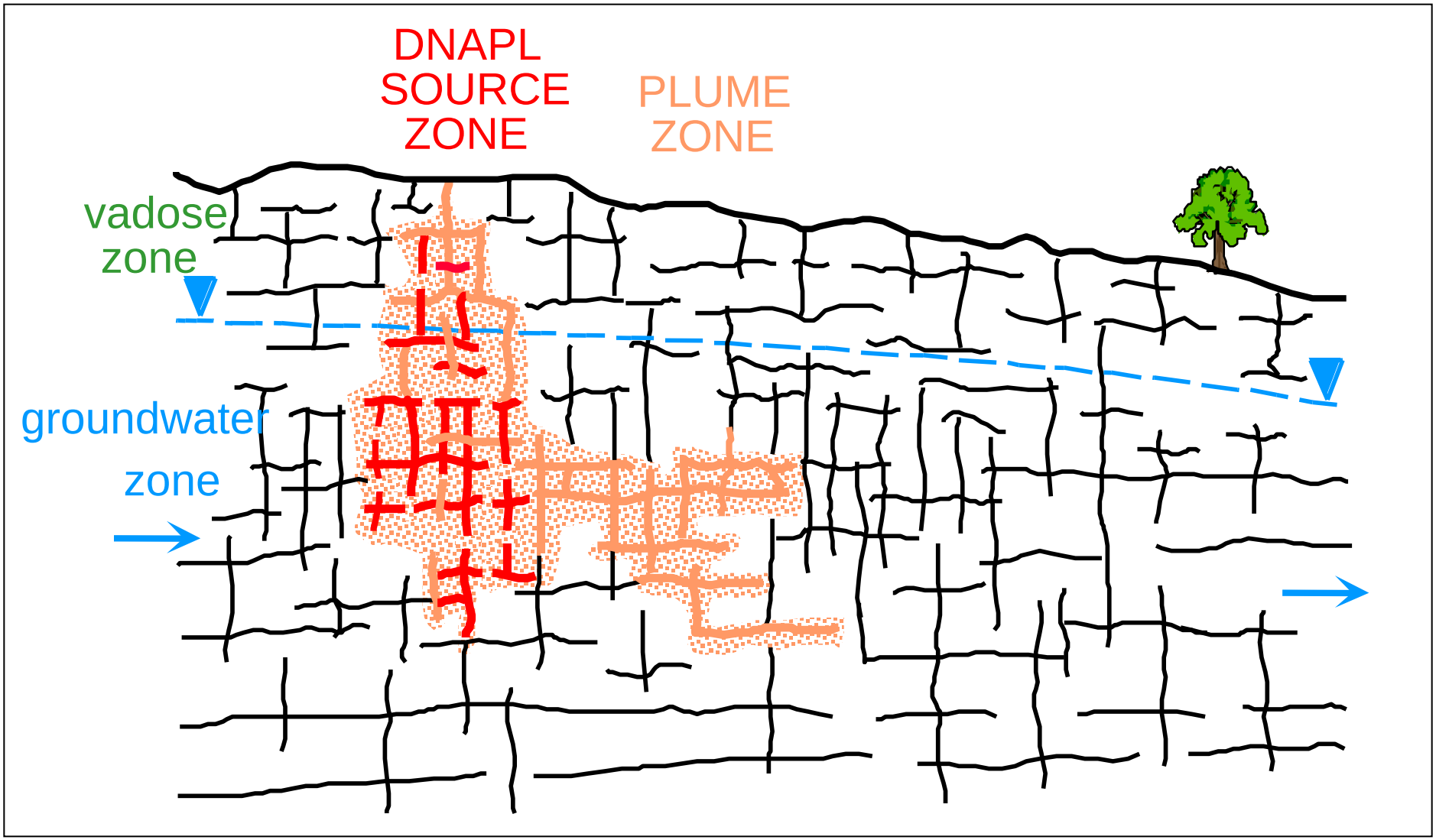
- **Matrix diffusion can attenuate the rate of plume migration in fractured bedrock relative to the rate of groundwater flow**
- **Transport parameters such as matrix porosity (18-40%), fracture porosity, hydraulic gradient, and the matrix retardation factor were characterized.**



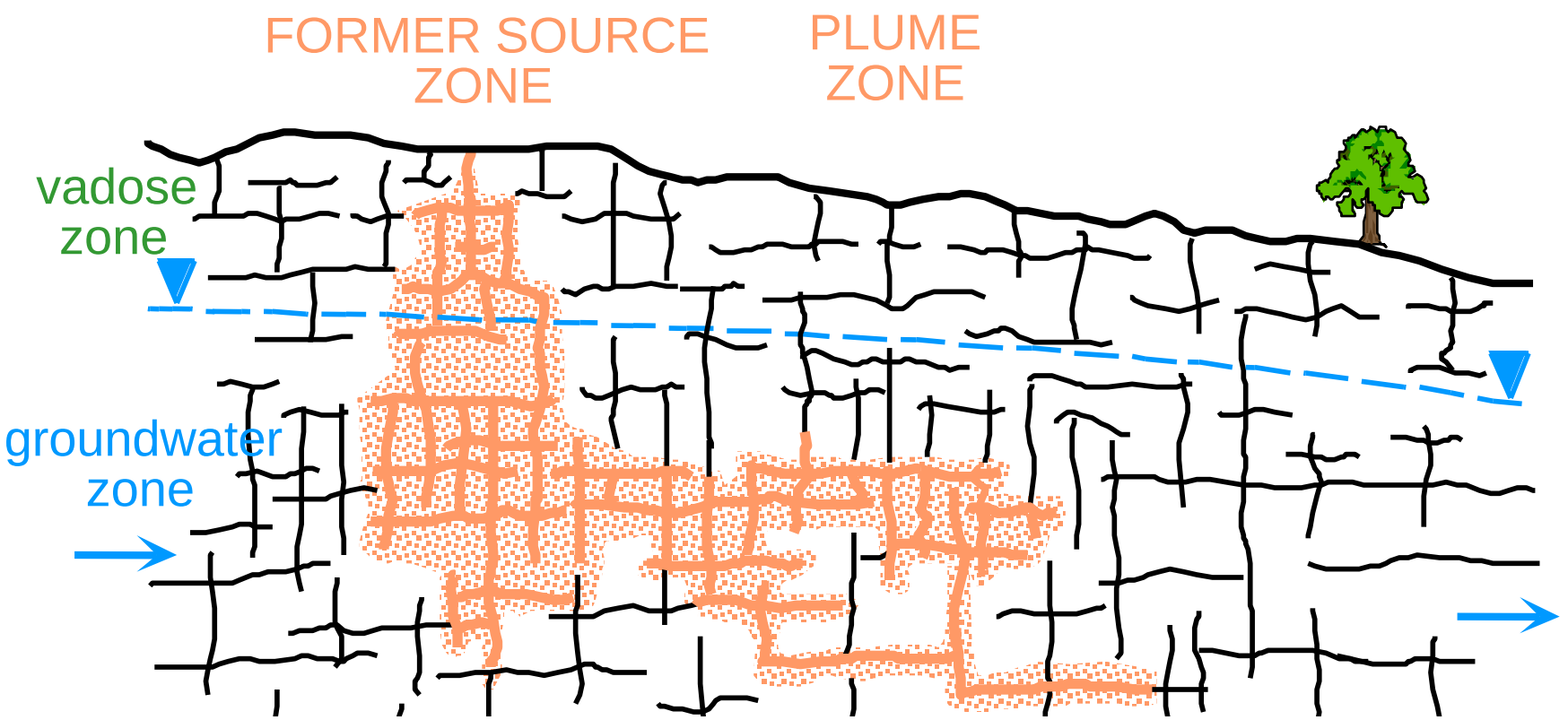
# Stage 1



# Stage 2



# Stage 3 (Current Stage)




Plume front is stable

# Conclusions

- **Status**
  - TCE detected at 1000 feet – total depth unknown
  - Springs on the side of the mountain impacted
  - Investigation report due by the end of the year but possibly inadequate
  - Technology unknown for total clean-up but anticipated to take a century

# White Sands Test Facility

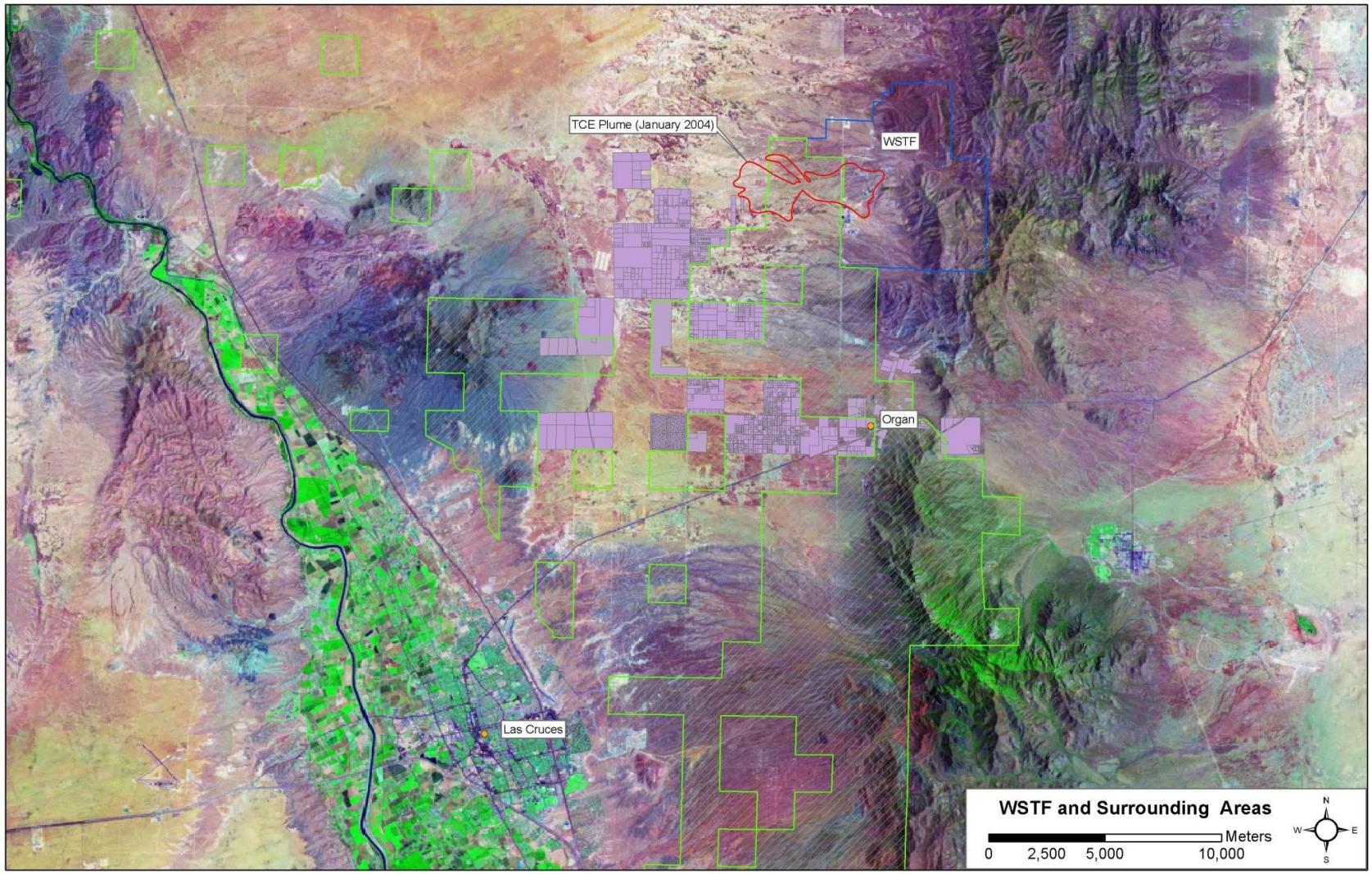
# History

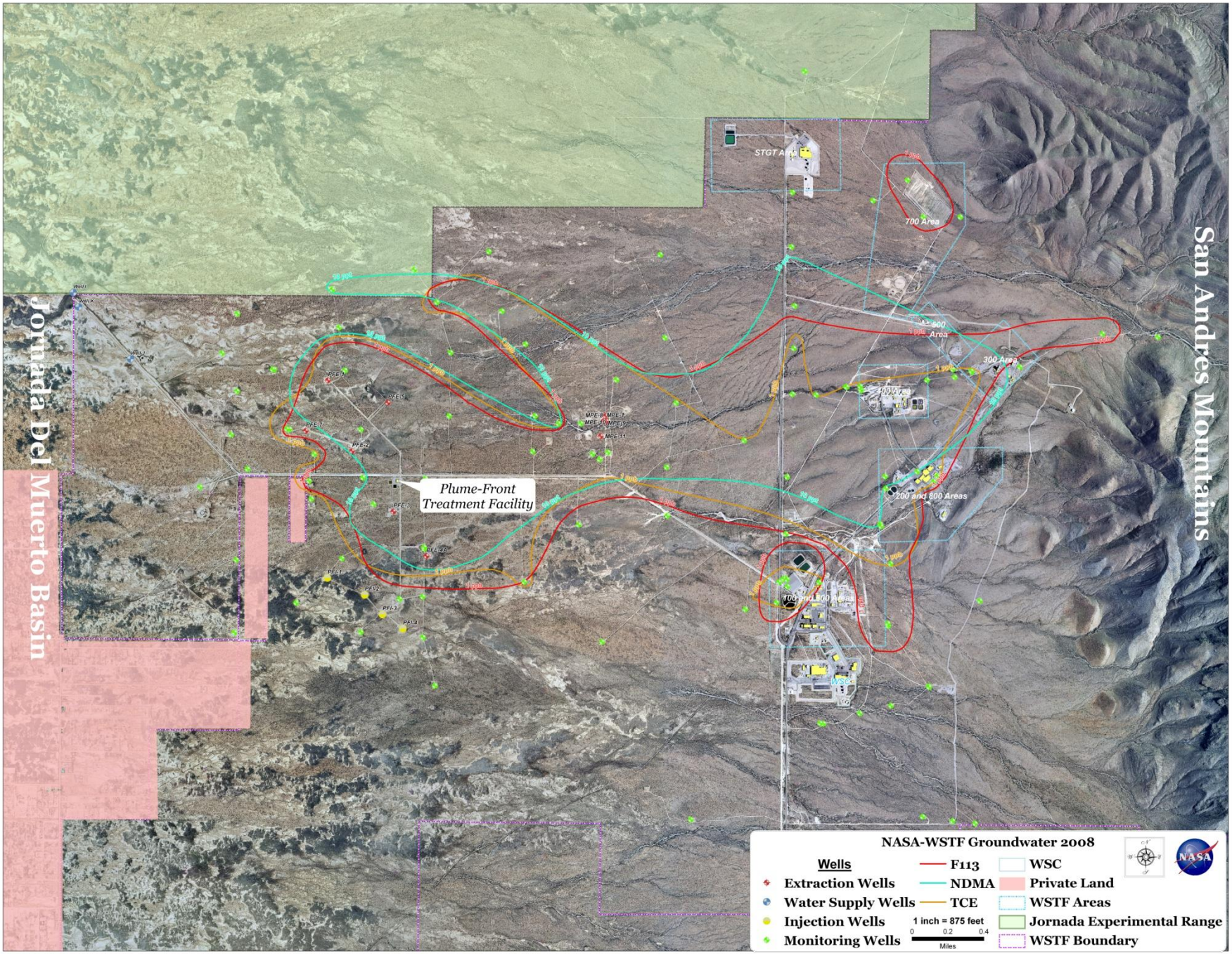
- **WSTF Groundwater and Soil Contamination occurred during the Apollo Era**
  - Rocket Engine Testing Operations
    - N-Nitrosodimethylamine (NDMA), cancer risk
    - N-Nitrodimethylamine (DMN), cancer risk unknown
  - Tank and Holding Pond Leakages
    - Trichloroethene (TCE), toxicity risk
    - Tetrachloroethene (PCE), toxicity risk
    - Various Freons, toxicity risk
- **NASA HQ tracks the contamination as a >$300M liability**

# Current Condition

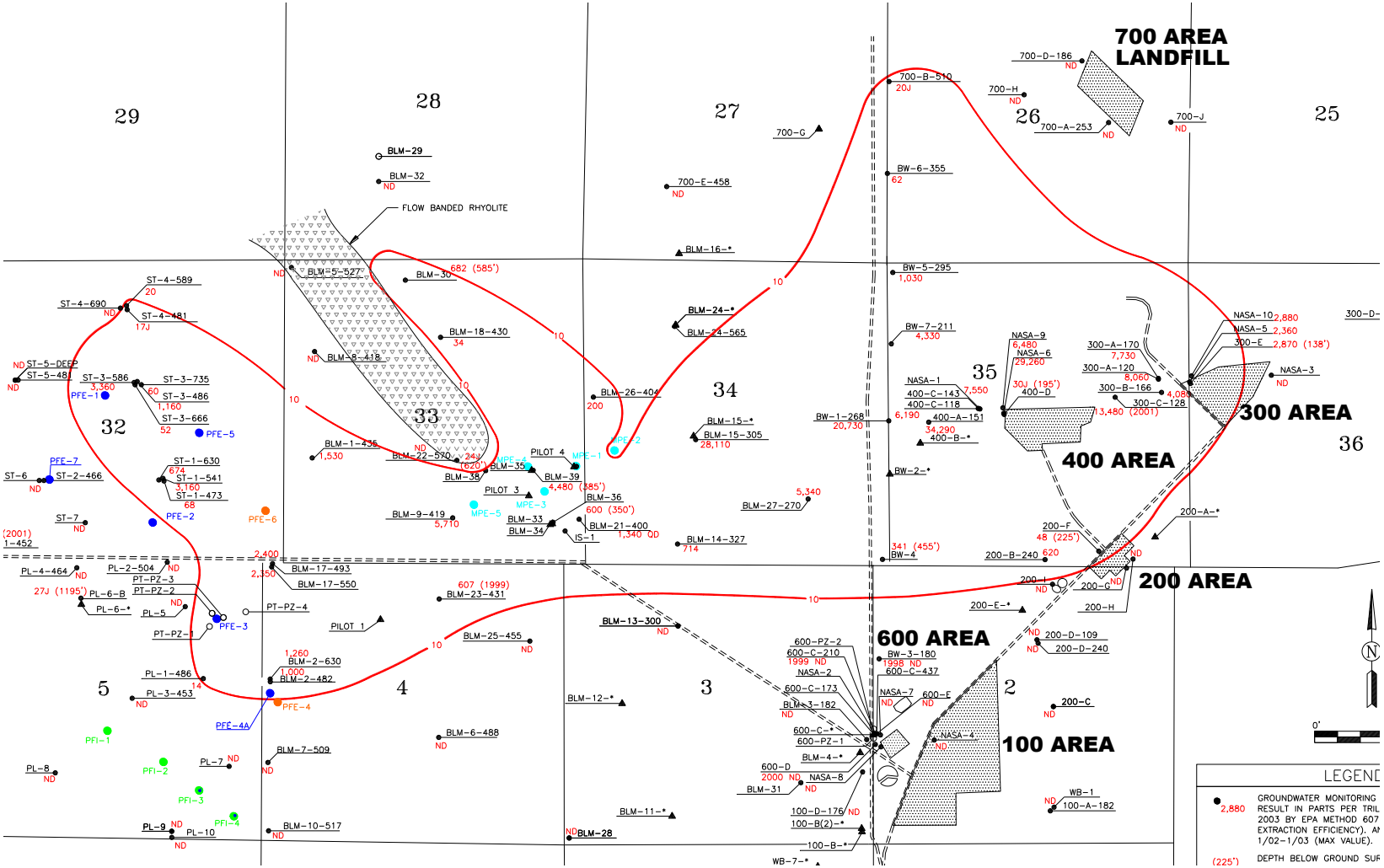
- **Hazardous constituents were detected in WSTF's ground water (~1987)**
- **Groundwater Contamination Plume**
  - Plume is ~ 4 miles long, 2 miles wide, and up to 800 feet thick
  - Plume front is advancing very slowly (feet/year)
  - Over 100 active monitoring wells with 222 discrete zones being used to define the plume
  - NDMA is health risk driver with cleanup target less than 10 ppt
- **Expected to take at least several decades to a century to achieve cleanup**

# N-Nitrosodimethylamine (NMDA) Plume

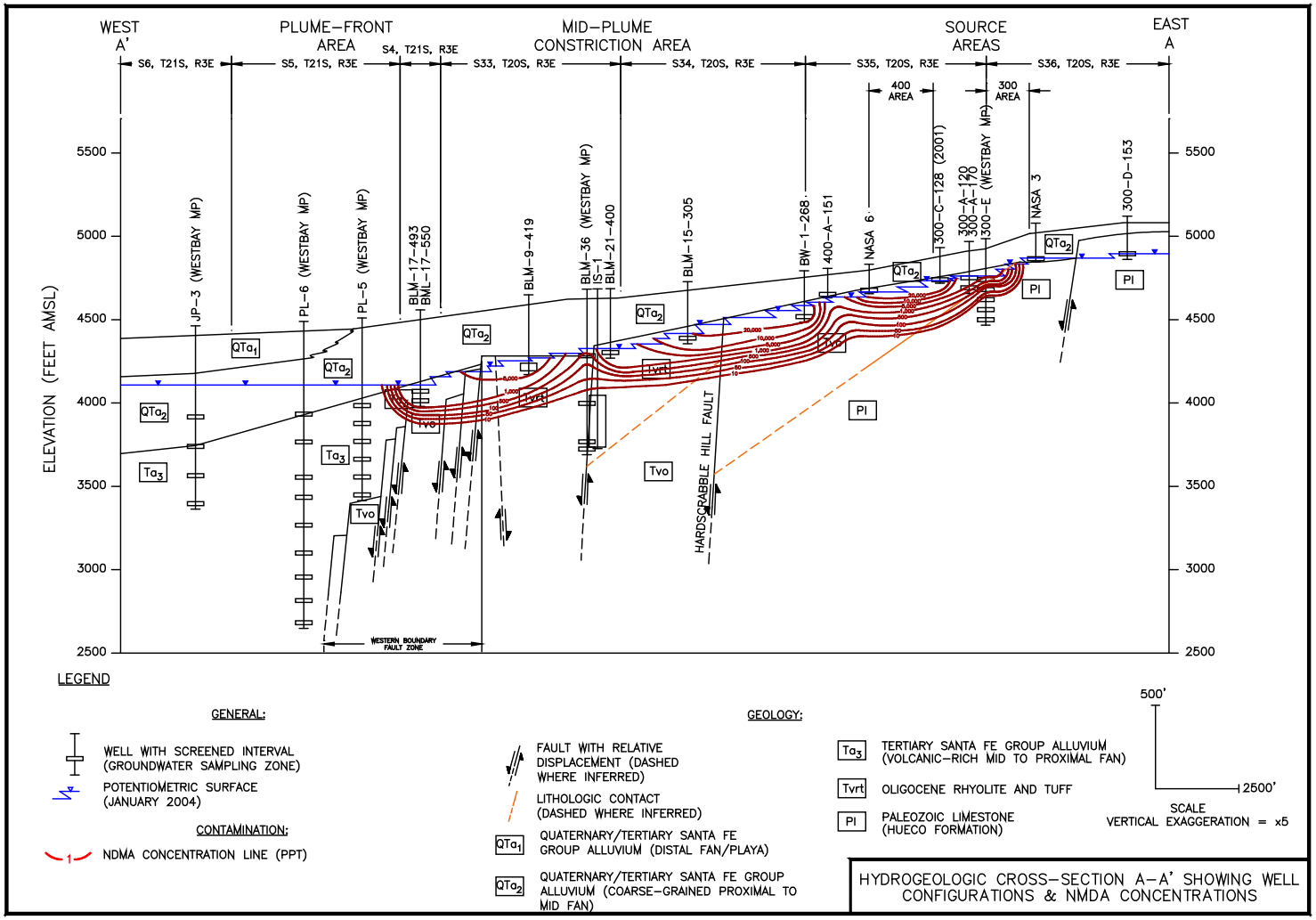



Jornada Del Muerto Basin
San Andres Mountains
Plume-Front Treatment Facility
STGT Area
700 Area
600 Area
300 Area
200 and 800 Areas
100 and 1300 Areas
NDMA
WSC
NASA-WSTF Groundwater 2008
Wells
Extraction Wells
Water Supply Wells
Injection Wells
Monitoring Wells
F113
NDMA
TCE
1 inch = 875 feet
0 0.2 0.4
Miles
WSC
Private Land
WSTF Areas
Jornada Experimental Range
WSTF Boundary
NASA

# N-Nitrosodimethylamine (NMDA) Plume



# Plume Cross-section

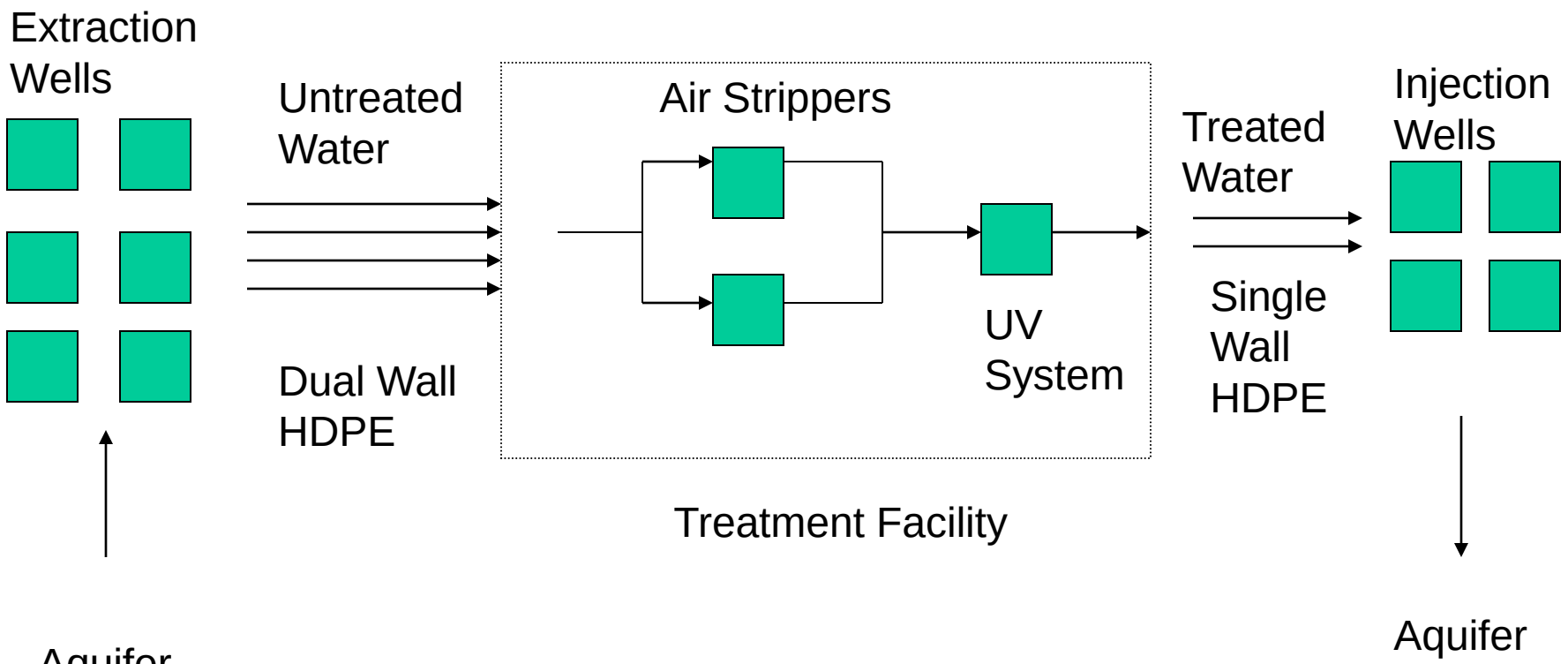


# Philosophy

- **Objective: Characterize, clean up, and "restore" contaminated areas**
- **Approach:**
  - Greatest health-risk liability pursued initially (groundwater contamination)
    - Plume Front
    - Mid Plume
    - Five Source Areas
    - Remaining solid waste management units
  - Soil Contamination
    - Initial investigations completed
    - Additional source area investigations planned

# Plume Front Remediation

Objective: Prevent further westward migration of the contaminant plume



# Source Areas

- **5 source areas**
- **All are about 125 feet to groundwater**
- **All have residual vadose zone contamination remaining**
- **All were capped for stabilization in the late 1980's**
- **The propulsion test areas in particular are troublesome due to NDMA only being semi-volatile**
- **No in-situ technology available to handle soils**

# Summary

- **NASA will be in the remediation business for a long time**
- **Technologies for application to these challenges need to be developed or improved to achieve cleanup**
  - At all
  - Or at least by the next century
- **Partnerships with others who have similar situations are the most effective way to achieve this.**